ARMY RESEARCH LABORATORY

Electrical Vehicle Stopper Evaluation, Phase III—Jaycor

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Electrical Vehicle Stopper Evaluation, Phase III—Jaycor

Mark Berry, Todd Turner, and Christian Reiff

Sensors and Electron Devices Directorate

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Abstract

This report discusses the results of the Electrical Vehicle Stopper Evaluation (EVSE) program phase III evaluation of the Jaycor Auto Arrestor vehicle stopper device. The Auto Arrestor directly injects a large current pulse into the underside of the vehicle and stops the vehicle by damaging the electrical components. This report also discusses the field evaluation of safety, ease of use, and effectiveness of the device.

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1. Introduction

The U.S. Army Research Laboratory (ARL) and the National Institute of Justice (NIJ) conducted an evaluation of contractor-developed devices that claim to stop vehicles in a nonlethal manner. This evaluation was conducted under a four-phase program called the Electrical Vehicle Stopper Evaluation (EVSE) program. In phase I, a *Commerce Business Daily* (CBD) notice was posted that requested submissions of proposed concepts or devices to electrically stop commercial vehicles. Phase II consisted of a laboratory evaluation of a subset of the submitted devices and/or concepts on a chassis dynamometer. (A chassis dynamometer is a set of rollers on which the vehicle's drive wheels are placed, and the vehicle can be driven with a remote control at highway speeds.) Phase III, described in this report, is a field test evaluation of vehicles on a roadway. Phase IV will be an evaluation by law enforcement personnel. Phase I was documented in the report *Electrical Vehicle Stopper Evaluation—Phase I*, by Berry and Brisker [1]. Phase II, for Jaycor, was documented in the report *Electrical Vehicle Stopper Evaluation: Jaycor*, by Berry, Turner, and DeTroye [2]. The overall phase II report was the *Electrical Vehicle Stopper Evaluation—Phase II Final Report*, by Berry et al [3].

The EVSE program is being conducted so that law enforcement agencies can end high-speed chases and protect public and military facilities. In the previous laboratory experiments, Jaycor participated in the evaluation under its own internal funding. For the phase III field test, NIJ funded Jaycor for continued development of its system and field test participation.

We conducted the phase III field test evaluation at the Maryland Police and Correctional Training Commission's driver training facility in Sykesville, MD. The site has two track test areas in which the phase II tests were conducted. The first test area is a large (approximately 1 mile) loop track, called the highway track. A drawing of the highway track is shown in figure 1. The track is paved and has a long straight section (speeds up to 90 mph can be achieved on the straight section). The track also has short straight sections of roadway inside the track, which simulate highway exit and entry ramps. The second test area is a city-type arrangement. A drawing of the city area is shown in figure 2. The city track contains curbing, streetlights, stop signs, etc, which are designed to simulate urban driving scenarios. During the Jaycor evaluation, only the highway track was used.

In this evaluation, ARL, NIJ, and Jaycor coconducted the experiments. Jaycor was responsible for providing its device and personnel to operate its device, drive the vehicles, and consult on the test conduct. The test plan for the experiments is in the appendix. Deviations from the test plan occurred during the experiments because of device failures. The Jaycor device did

Figure 1. Driver training facility highway track.

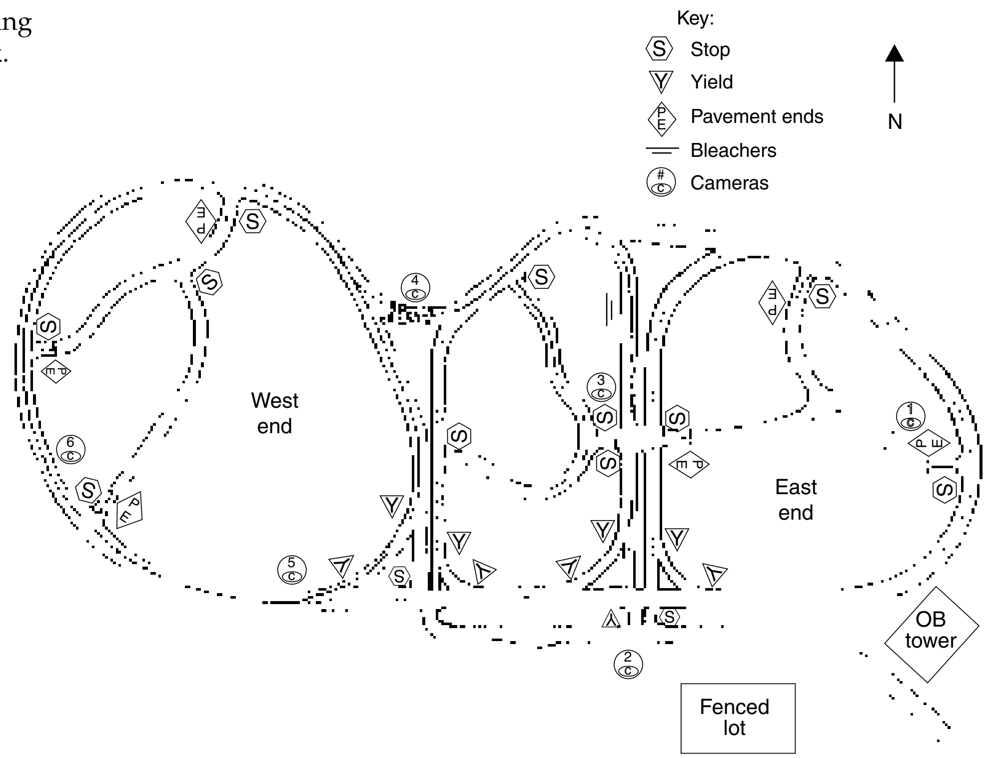
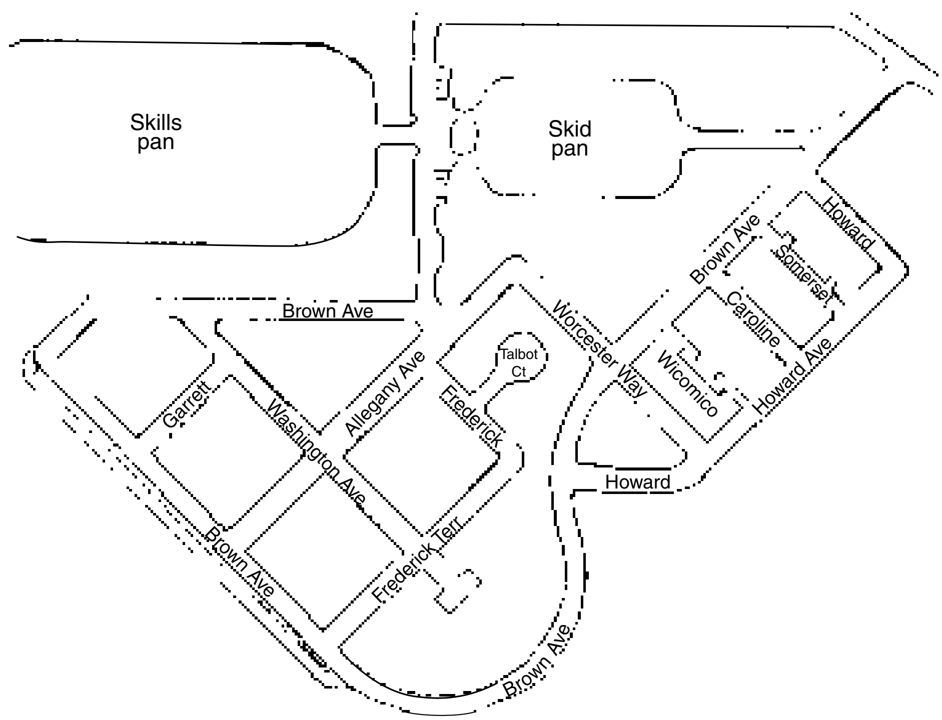


Figure 2. Driver training facility urban track.



not survive the test series and was only tested against one vehicle—the 1991 Ford Taurus. A contract mechanic repaired and examined the vehicle in the local area of the test site before the test period to ensure that it was operating properly. The mechanic also examined and repaired the vehicle after the test series to determine the damage created by the device.

2. Experimental Description

The experiments were conducted from 19 to 21 June 2000. Two shots were fired during the test period at the target vehicle. The test layout is shown in figure 3. As the figure depicts, the vehicle was driven over the test device. Since the reaction of the vehicle and driver could not be predicted beforehand, a safety zone was set up around the test device. This safety zone was hyperbola-shaped (marked by orange traffic cones) to keep people away from the device as well as the vehicle path. Two test scenarios were used during the test period: constant speed and standing start. (The test plan in the appendix shows a third scenario that was not used because of device failures.) We chose these two scenarios because they answer law enforcement's goal to end high-speed chases (constant-speed scenario) and stop vehicles at border crossings (standing-start scenario). The response of the vehicle electronics should be the same in both scenarios. The device was tested in a dry configuration only during the test period.

For the constant-speed scenario, the vehicle was tested at 60 mph. The vehicle was accelerated to 60 mph and was driven over the test device. If the vehicle survived the experiment, it was used for a second run. We measured the vehicle speed using the vehicle's speedometer and up to three *X*-band SpeedChek Personal Sports Radars.

For the standing-start scenario, the vehicle was stationed approximately 45 ft from the stopping test device and was accelerated from a standing start and driven over the device. The speed at the device was measured with a SpeedChek Personal Sports Radar.

Field measurements were taken outside the vehicle during the test period. During the test runs, a field probe was placed near the direct injection device to determine the radiated field levels to which a pedestrian near the device might be exposed (approximately 5 ft from the device). Internal measurements were taken on one vehicle during phase II of the program

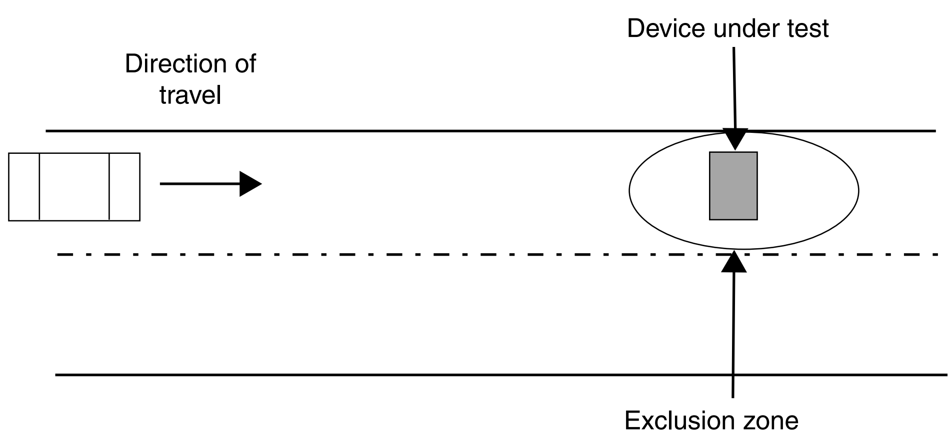


Figure 3. Experiment layout for direct injection field test.

(in phase III, radiated field levels were not measured inside the vehicle because the device did not survive long enough for those measurements to be conducted). The same field probe that was used in phase II, as well as a monopole probe, was also used to measure the field levels outside the vehicle at the 5-ft location to determine the exposure levels for a pedestrian or operator. All the experiments were documented with a video camera as well as with a digital camera.

Four types of effects on vehicles were possible during the experiment. The first is no effect, which means the Auto Arrestor had no effect on the vehicle. The second effect is a stumble, which is a momentary response that lasts as long as the interaction between the Auto Arrestor and the vehicle. The third effect is a soft kill, which is when the vehicle engine is stopped but can be restarted by either a hot restart (key not turned off first) or by resetting the key (key cycle). A vehicle that has experienced a soft kill can be restarted even with the vehicle still rolling. The fourth effect is a hard kill—the vehicle is stopped and cannot be restarted.

3. Description of Device

Jaycor proposed a technique to stop moving vehicles that involved the direct injection of electrical current into the subframe and engine of a vehicle. The Auto Arrestor is shown in figure 4. The device is considered to be in the brass-board stage of development. The electrodes on the road plate were a fixed length (about 14 in.) and were not adjustable. The electrodes (negative and positive) touch the subframe and engine and transmission of the car. When a connection is made, the device arcs to the subframe and engine and transmission, delivering current into the vehicle.

Two versions of the Auto Arrestor were brought to the phase III test site. The first device was the same one that was brought to ARL in phase II of the program. This device was driven about 25 percent harder (two-stage Marx generator at a higher voltage of about 180 kV) than it was in phase II. The second device was a smaller unit with a three-stage Marx generator. Each capacitor was charged to about 60 kV, providing a 180-kV pulse out of the unit. Both devices used the same road plate to interact with the vehicle. This road plate was a single-lane, rigid device that was not portable. As part of the development program, Jaycor designed and built a multilane road plate that could be rolled up and placed in the trunk of a car. This device was not used and was found by Jaycor to be too inductive to be used to stop vehicles (the inductance limited the current delivered to the vehicle, especially in the far lane). Figure 5 shows the larger device, and figure 6 shows the smaller device.

The Auto Arrestor is a stationary, one-man-lift semiportable device that is activated by an operator just before the target vehicle passes over the device. It is hoped that the spring-loaded electrodes, depicted in figure 7, will

Figure 4. Jaycor Auto Arrestor device.

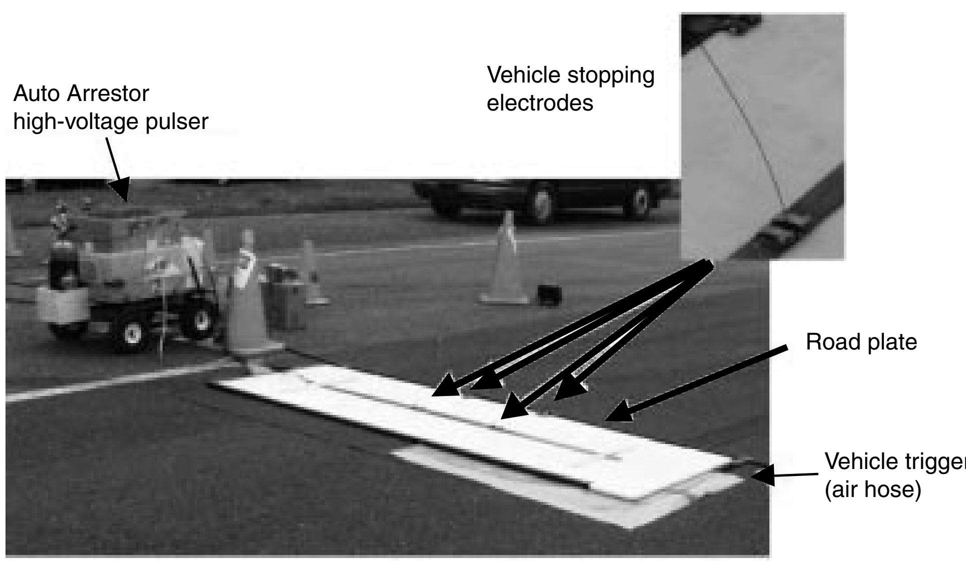


Figure 5. Jaycor Auto Arrestor large device (laboratory version).

Figure 6. Jaycor Auto Arrestor small device (preprototype).

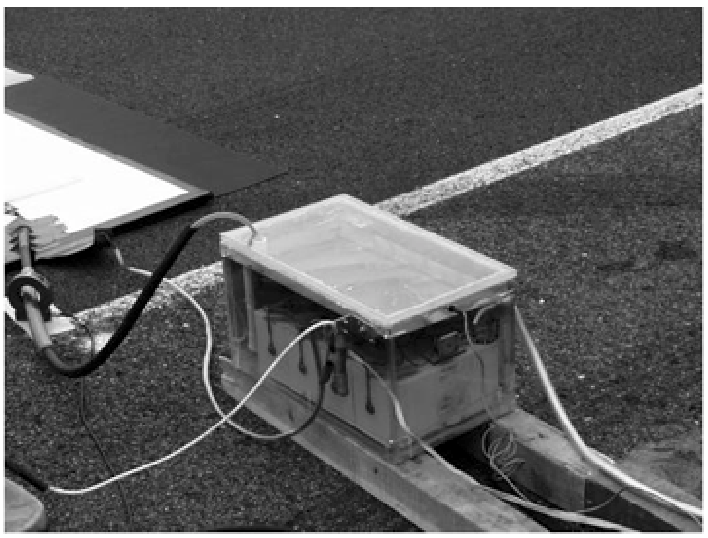
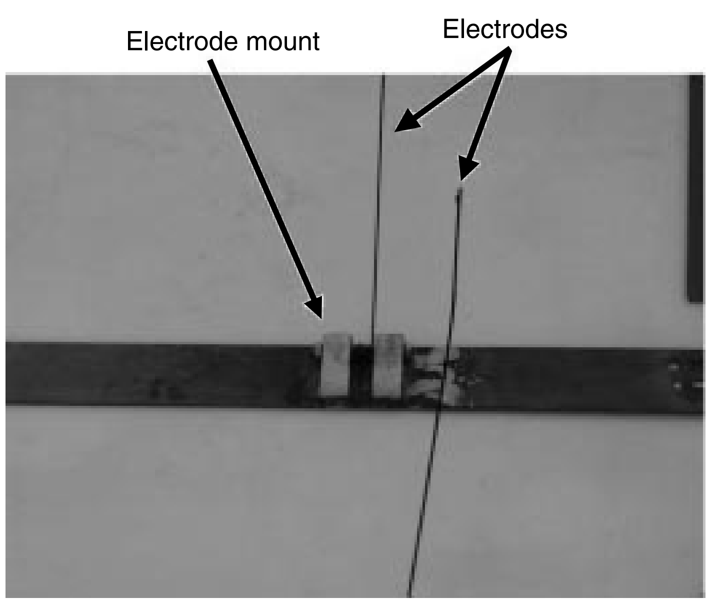


Figure 7. Road plate electrodes.



contact the vehicle between the frame and the engine as the vehicle passes (fig. 8) (although contact is not necessary since enough voltage exists to cause arcing to those areas), causing current to be induced in electrical components in the engine. The device is armed when the operator pushes the arming switch, but the road plate is not armed until the vehicle crosses over the device trigger. There is no voltage on the electrodes until an air-actuated switch (triggered by the vehicle driving over an air hose placed in front of the device) causes a switch to close and energize the electrodes.

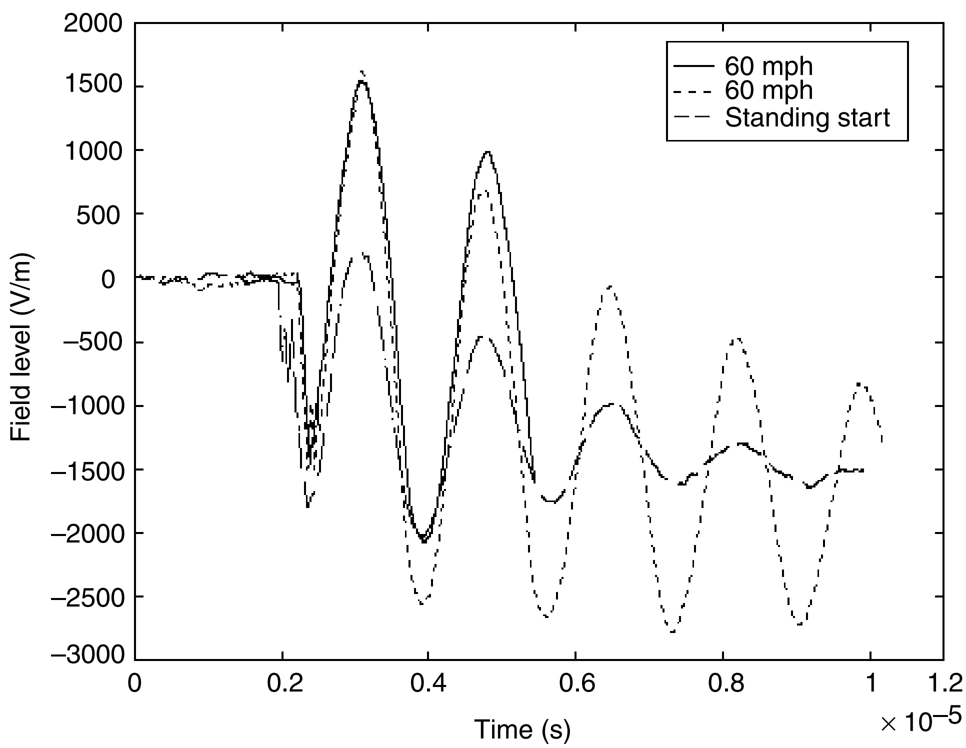
Figure 8. Vehicle passing over road plate.

4. Human Hazard

We used an EG&G ACD-7 field probe antenna to do the external field mapping on the runs with the Ford Taurus. Field measurements were taken at approximately 5 ft from the device. The *IEEE Standard for Safety Levels with Respect to Human Exposure to RF Electromagnetic Fields, 3 kHz to 300 GHz*, states that for a single pulse, the field level cannot exceed 100 kV/m [4].

The radiated field levels outside the vehicle were approximately 1.5 to 3 kV/m, which is well below the IEEE standard. Figure 9 shows the field levels for the three shots on the Taurus. These levels are much lower than those levels that were measured during phase II. This difference is probably because, in phase II, the fields were measured in a metal room with a large metal dynamometer under the vehicle. There is still, however, some concern of a potential hazard because the voltage electrodes may remain charged until shorted, which is when the device is armed. An unwary individual who touches these electrodes when the device is armed may receive a hazardous shock. The contractor stated that the electrodes are not armed unless the operator energizes the unit and the vehicle passes over the device trigger.

Figure 9. Field levels produced at 5 ft.



5. Experimental Results

Because of device failures, only three shots were taken on the 1991 Ford Taurus during the experimental period. The first shot was taken at a constant speed of 60 mph, and the trigger for the device (air-hose actuator) was placed between the positive and ground electrodes. There was no effect during the first shot. Before the second run, the trigger was moved to approximately 6 in. in front of the road plate. During the second shot, a stumble and soft kill was obtained during a 60 mph run. The vehicle was upset and had only enough power to maintain a 40 to 45 mph speed. The vehicle was brought to a stop, and the key was turned off. The vehicle was then restarted and operated as it did before it was tested (i.e., normal operation). For the third shot, the Taurus was driven over the device from a standing start (speed of about 20 mph obtained). In this run, the Taurus suffered a hard kill and was not restartable. The vehicle was sent to be repaired and was found to suffer damage to the ignition module as well as the electronic engine control (EEC) unit.

After the three test runs, the large Auto Arrestor device was broken (spark-gap problems) and the second (small device) was installed to be tested. The small suffered three burned-out charging resistors in the Marx generator and could no longer be repaired during the test period. The contractor stated that the units were designed to operate in a high-altitude climate (Colorado Springs is Jaycor's office, and it is 6000 ft above sea level) and that the spark-gap pressures and gaps were not appropriate for an altitude of 500 ft above sea level.

6. Conclusions

It was hoped that the Jaycor device would survive the experimental test period and would complete the test runs on all the vehicles. At this point, insufficient data exist to properly evaluate the Jaycor Auto Arrestor. The device seemed to effectively stop the Ford Taurus (once the trigger was properly placed). The device also generated electric fields that were well below the IEEE standard. It is recommended that the device be reworked for field use and reevaluated.

References

1. M. Berry and H. Brisker, *Electrical Vehicle Stopper Evaluation—Phase I*, U.S. Army Research Laboratory, ARL-TN-87, April 1997.

2. M. Berry and T. Turner, *Electrical Vehicle Stopper Evaluation: Jaycor*, U.S. Army Research Laboratory, ARL-TN-85, April 1997.

3. M. Berry, T. Turner, G. Tran, C. Lazard, S. Kaplan, and H. Brisker, *Electrical Vehicle Stopper Evaluation—Phase II Final Report*, U.S. Army Research Laboratory, ARL-TR-1374, May 1997.

4. *IEEE Standard for Safety Levels with Respect to Human Exposure to RF Electromagnetic Fields, 3 kHz to 300 GHz*, Institute of Electrical and Electronics Engineers, Inc., IEEE Std C95.1, 1999.

Appendix. Test Plan for Electrical Vehicle Stopper Evaluation Program, Phase III

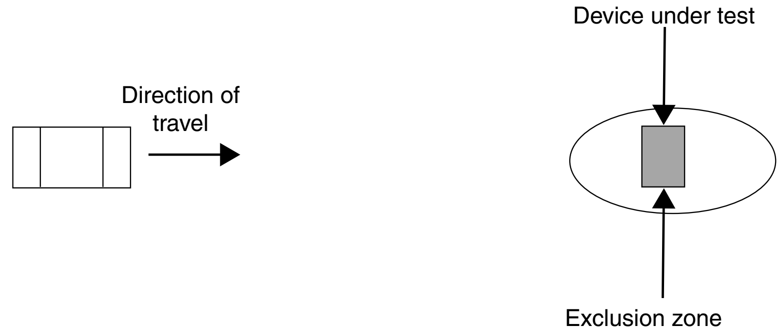
Background: As part of phase II of the electrical vehicle stopper evaluation (EVSE) program, the U.S. Army Research Laboratory (ARL) evaluated two direct injection and three microwave concepts or devices with respect to effectiveness, ease of use, and safety. These evaluations were conducted in the laboratory on a chassis dynamometer. For phase III, ARL will evaluate systems in the laboratory (if required), as well as in the field. Two contractors responded to the request for proposals (RFP) published by the National Institute of Justice for phase III. Both contractor devices were evaluated at ARL and were found to be safe and effective. According to the first contractor, the device has not changed from the device that was evaluated in phase II. The second contractor's device will have an increased output of about 25 percent. The increase in output should increase the measured field levels by the same factor. With this in mind, we will not need further laboratory evaluation of either contractor's device as the field levels will not increase more than 25 percent (i.e., they are still below relevant standards). During the experimental series, up to 20 vehicles will be used for each contractor's device. Once a vehicle is damaged, attempts will be made to repair the vehicle during the test period.

Test location: The field test for phase III will be conducted at the Maryland Police and Correctional Training Commission's driver training facility in Sykesville, MD. The site has two areas in which the test series may be conducted. The first area is a large (approximately 1 mile) loop track. The track is paved and has several straight sections (speeds up to 90 mph can be achieved on the straight sections). The track also has approximately ¼-mile straight sections in between. The second test area is a city-type arrangement. At the site, available support includes automobile repair shops, gasoline fuel, and generators for powering data acquisition equipment. There are also hotel accommodations within 30 miles.

Test period: Each contractor will be given a week to test up to 20 vehicles. The actual number of test runs during that time will depend on the reliability of the contractor-provided test device, the amount and severity of vehicle damage, and the vehicle-repair turnaround time. At this time, the amount of damage or the repair turnaround time cannot be predicted. A minimum of three different vehicles will be used for each test scenario.

Test layout: The field test layout is shown in figure A-1. As the figure depicts, the vehicles will be driven over the test device. Since the reaction of the vehicle and driver cannot be predicted, a safety zone will be set up around the test device. This safety zone will be hyperbola-shaped to keep people away from the device as well as the vehicle path.

Figure A-1. Field test layout.



Test vehicles: At least 15 vehicles will be used during the test series for each contractor. Table A-1 is a template for the planned test series. The vehicles listed in the template are for illustration only (the actual vehicles tested may be different). The effect of the test device on the target vehicle and a detailed list of any vehicle parts damaged will be noted for each test in the series.

Test scenarios:

1. Constant speed: A minimum of three vehicles will be used for each of the speed experiments. Each vehicle will be accelerated to 60 mph and will be driven over the device. If the vehicle survives the experiment, a second run will be conducted in which the vehicle will be accelerated to 40 mph. If the vehicle survives again, it will then be tested at 20 mph. The vehicle speed will be measured by the vehicle's speedometer. If the speedometer is not functional, the speed will be measured with a portable radar speed detector. (A total of at least nine vehicles will be used for the constant-speed test series.)
2. Standing start: A minimum of six vehicles will be used for this experimental series. The vehicle will be stationed approximately 50 ft from the stopping device and will be accelerated from a standing start and driven over the device.
3. Wet direct injection device: The devices will be tested to determine if they are affected by rain. Once most of the testing is complete and if it has not rained during the test period (i.e., the device has not been tested wet), the device will be soaked with water. The device self-breakdown will be examined first. The device will be energized to its operating voltage to determine if water causes it to break down. If the device does not break down, then the underside of one test vehicle will be soaked with water and the vehicle will be driven over the device.

Field measurements: Once a vehicle is damaged and cannot be easily repaired, it will be used for field measurements. The vehicle will be parked over the direct injection device and will be pulsed. The same field probe that was used in phase II will be used to measure the fields inside the vehicle at each passenger position. It will also be used to measure the fields on the outside of the vehicle at 3, 10, 20, and 50 ft to determine the exposure levels for a pedestrian or operator. The experiments will be documented with a video camera as well as with a digital camera.

Table A-1. Test plan template.

Vehicle	Standing start	20 mph	40 mph	60 mph
1990 Toyota Corolla				
1988 Toyota pickup				
1998 VW Jetta				
1987 Mercedes 300E				
1989 Dodge Dakota				
1988 Chevy Blazer				
1989 Ford Probe				
1993 Cadillac Fleetwood				
1990 Ford Taurus SHO				
TBS (additional vehicles)				

TBS = To be specified

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13. ABSTRACT *(Maximum 200 words)*

This report discusses the results of the Electrical Vehicle Stopper Evaluation (EVSE) program phase III evaluation of the Jaycor Auto Arrestor vehicle stopper device. The Auto Arrestor directly injects a large current pulse into the underside of the vehicle and stops the vehicle by damaging the electrical components. This report also discusses the field evaluation of safety, ease of use, and effectiveness of the device.

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